III. PROJECTED ECONOMICS

CAPITAL AND OPERATIONS AND MAINTENANCE COSTS FOR THE PROJECT ONLY

Thus far, operations and maintenance costs have not been incurred by the project. All costs incurred so far have been due to design, construction and startup of the system. The cost of the project to date has been approximately $563,000, as shown in Table 2.

Table 2.
Costs of the Enhanced Landfill Demonstration Project

COST AREA	CAPITAL COST
Project Capital Costs	
Construction of Base Liner	$114,000
Construction of Clay Levees	$120,000
Construction of Waste Monitoring System	$40,000
Construction of Landfill Gas Collection and Removal System	$34,500
Construction of Leachate Recirculation/Pumping System	$47,500
Construction of Cover System	$52,000
Initial Cell Operation and Testing	$7,000
S[illegible]TOTAL OF CAPITAL COSTS	**$415,000**
[illegible]ect Associated Costs	
Design of all Systems	$73,000
Project Final Report and Quarterly Reporting	$25,000
Project Contingencies	$50,000
SUBTOTAL OF ASSOCIATED COSTS	**$148,000**
TOTAL PROJECT COST	**$563,000**

Note: See project budget to get the $ amounts.

Estimated operations and maintenance costs over the first two years of the project monitoring phase are shown in Table 3.

Table 3.
Projected Operations, Monitoring, and Maintenance Costs, First Two Years.

CATEGORY	COST
Laboratory	$15,000
Personnel	$158,000
Surveying	$2,000
General Contingency	$10,000
Outside Consultant	$10,000
General Maintenance	$25,000
Total Over Two Years	$220,000

Note: Costs will drop off with time as frequency of measurements decrease.

COSTS FOR A COMMERCIAL SYSTEM

Construction costs at the Yolo County Central Landfill can be used to estimate construction costs for a commercial scale system. Waste Management Units are constructed and filled at the landfill about every three years. These units cover 22 acres with a maximum depth of solid waste of about 58 feet. Solid waste inflow averages between 450 and 500 tons per day.

Capital and operating costs for application of enhanced landfill technology are only those incurred above and beyond the cost of conventional landfilling. For cost analysis purposes it is important to recognize that whatever containment design is used, *most* of the cost of landfilling is incurred as part of basic environmental protection and is independent of whether methane enhancement is practiced. For example, costs common to enhanced and conventional landfilling include:

- A base liner system and a leachate collection and removal system
- Waste coverage with a low permeability liner is required in any event.
- The installation of a landfill gas recovery system is required if certain emissions criteria are to be met. These criteria are set forth in the Federal Clean Air Act and by local air pollution control districts.

- All normal operation and maintenance work will be incurred in any case.

BASE LINER COST

Current state regulations in California prohibit the introduction of liquids, including leachate for recirculation, into a Class III Waste Management Unit. A goal of the project is to demonstrate that liquid addition and leachate recirculation can be practiced without causing a buildup of hydrostatic head on the landfill liner. It is hoped that the data gathered through this project will show that a single-lined landfill provides adequate environmental protection, however, the State Water Quality Control Board may continue to require double-lined systems. To account for such uncertainties, three cases are submitted and examined from a cost perspective.

Option 1	Single-lined landfill cell (Drawing III-1).
Option 2	Double-lined cell with a cross section identical to that used in the enhanced cell for the project (Drawing III-2).
Option3	Double-lined cell using a cross section similar to that used in a liquid waste surface impoundment existing at the Yolo County Central Landfill (Drawing III-3).

Costs for landfill construction for each option on a per acre basis are provided in Tables 4, 5, and 6. Option 1 describes the cost of base liner construction if leachate recirculation is not practiced or double containment is not required. The difference between Options 2 and 1 or between Options 3 and 1 is the incremental increase in costs that can be assigned to enhanced landfilling.

Table 4
Component Costs of an Enhanced Landfill, Option 1
(Single composite liner system)

Base layers: (Listed from the bottom up)	Costs per Acre
Purchase and Transportation of Soil ($2.50/yd^3)	$19,000
Compacted clay liner (2 feet clay)	$12,000
60 mil HDPE base membrane	$15,000
HDPE geonet (drainage layer)	$8,000
Geotextile	$8,000
Operations layer	$6,000
HDPE pipes, 4" diam.	$4,000
(Leachate collection and removal system, LCRS)	
Subtotal base layers for Option 1:	$72,000
Other associated costs:	
Engineering and Design (8%)	$5,800
Quality assurance/quality control for construction	$12,000
Contingencies at 10 %	$7,200
Total other costs:	$25,000
TOTAL OPTION 1 COSTS	$97,000

Table 5
Component Costs of an Enhanced Landfill, Option 2
(Double lined using enhanced cell design)

Base layers (listed from the bottom up):	Cost Per Acre
Purchase and Transportation of Soil ($2.50/yd^3)	$45,000
Compacted clay secondary liner (2 feet clay)	$12,000
60 mil HDPE secondary liner	$15,000
HDPE geonet (secondary drainage layer)	$8,000
Geotextile (secondary liner)	$8,000
HDPE pipe, 2-inch diameter (secondary LCRS)	$2,500
Operations layer (secondary liner protection, 1.5 feet)	$9,000
Compacted clay primary liner (1 foot clay)	$6,000
60 mil HDPE primary liner	$15,000
HDPE geonet (primary drainage layer)	$8,000
Geotextile (primary liner)	$8,000
HDPE pipes, 4" diam. (Primary LCRS)	$4,000
Operations layer (secondary liner protection, 1 foot)	$6,000
Subtotal base layers for Option 2:	$146,500
Other associated costs:	
Engineering and Design (8%)	$11,800
Quality assurance/quality control for construction	$15,000
Contingencies at 10 %	$14,700
Total other costs:	$41,500
TOTAL OPTION 2 COSTS	$214,500

Table 6.
Component Costs of an Enhanced Landfill, Option 3
(Double lined using YCCL liquid waste surface impoundment design)

Base layers (listed from the bottom up):	Costs per Acre
Purchase and Transportation of Soil ($2.50/yd^3)	$19,000
Compacted clay liner (2 feet clay)	$12,000
60 mil HDPE, secondary liner	$15,000
HDPE geonet (secondary drainage layer)	$8,000
HDPE pipe, 2" diameter (secondary LCRS)	$2,500
60 mil HDPE, secondary liner	$15,000
HDPE geonet (primary drainage layer)	$8,000
Geotextile	$8,000
Operations layer	$6,000
HDPE pipes, 4" diam. (primary LCRS)	$4,000
Subtotal base layers for Option 3:	$97,500
Other associated costs:	
Engineering and Design (8%)	$7,800
Quality assurance/quality control for construction	$17,500
Contingencies at 10 %	$9,800
Total other costs:	$35,100
TOTAL OPTION 3 COSTS	$132,600

SURFACE LINER COST

Regulations governing landfills require that all landfills be covered with a low permeability liner after filling; this process is referred to as "landfill closure". Clay has been the most often used liner material but synthetic membrane liners are becoming increasingly popular due to the high cost of importing clay to landfills without on-site sources of clay. Coverage with a synthetic membrane makes possible the recovery of nearly all of the gas produced. Because landfill closure is a requirement of normal landfill operations it is not considered an added cost of enhanced landfilling. However, because it is necessary to maximize landfill gas capture, estimated per-acre costs for a surface liner system incorporating a geosynthetic membrane are shown in Table 7. Costs are estimated using construction costs at the Yolo County Central Landfill.

Table 7.
Component Costs of a Landfill Surface Liner System

Surface layers (listed from the bottom up):	Costs per Acre
Purchase and Transportation of Soil ($2.50/yd^3)	$16,000
Foundation layer (2 feet)	$16,000
Geotextile	$8,000
Geonet	$8,000
Geotextile	$8,000
40 mil LLDPE (linear low density polyethylene)	$15,000
Vegetative layer (1 foot)	$5,000
Hydroseeding	$1,500
Subtotal base layers for Option 3:	$77,500
Other associated costs:	
Engineering and Design (8%)	$6,200
Quality assurance/quality control for construction of base and	$12,000
Contingencies at 10 %	$7,800
Total other costs:	$26,000
TOTAL COST PER ACRE	$103,500

LIQUID HANDLING EQUIPMENT COST

Liquid addition and leachate recirculation can occur in a number of ways. Liquid can be applied to the waste as it is being placed or liquid can be added to a separate leachate collection and removal system upon final waste placement. Liquid can be added using the surface of the landfill as a leach field, through injection wells, or a combination of both. The quantity and timing of liquid additions would depend on the objective, such as methane gas enhancement, leachate management, rapid landfill stabilization, etc. A cost analysis for a commercial scale leachate recirculation system was not within the scope of this report. Rather, the Delaware Solid Waste Authority (DSWA) was contacted, as they have constructed large scale leachate recirculation facilities within the past several years. The DSWA system utilizes both leach fields and interconnected injection wells. The cost estimate of $10,000 per acre is approximate as it is difficult to separate the recirculation system costs from the overall landfill construction costs, but seems reasonable based on construction costs at Yolo County Central Landfill.

LANDFILL GAS RECOVERY AND UTILIZATION COST

The conventional manner of collecting landfill gas is to drill vertical wells after waste placement and connect them to horizontal headers. In some landfills, particularly large, deep landfills, horizontal collection pipes are placed to begin gas collection before the landfill is full. Another possibility, is to place a porous layer within the final cover that will transmit the landfill gas to horizontal collection pipes. This porous layer could consist of chipped tires or gravel. The Yolo County project uses a combination of vertical wells and a porous, horizontal collection layer.

Typically, the installation of a gas collection system would be required to control emissions and would not be installed solely to recover methane for utilization. The generation of energy with the collected landfill gas is an alternative to flaring of the gas which should have been collected anyway. Therefore, the cost of installing a landfill gas collection system would not be considered an incremental increase in operating costs resulting from landfill enhancement.

As enhanced landfilling has not been widely practiced on a commercial scale, the economics of landfill gas-to-energy projects are evaluated assuming conventional landfill practices. For this reason, it is difficult to consider the costs of energy generation as an increase in expenses that result from enhanced landfilling. However, if an investment were made in landfill gas to energy equipment with the intention of practicing enhanced landfilling, additional power generating capacity would be required to take advantage of the increased methane generation rate. In this case, the additional capacity could be compared to the incremental increase in revenue resulting from increased methane generation. Estimated costs for a hypothetical 1,000 kW plant are shown in Table 8.

INCREASED OPERATIONAL COSTS RESULTING FROM ENHANCED LANDFILLING

Again, much of the operational expense of collecting and utilizing landfill gas would be incurred regardless of whether or not enhanced landfilling were practiced. Estimated operational costs are shown in Table 9. Only the maintenance of the liquid handling equipment and the increased monitoring costs are considered to accrue from the practice of enhanced landfilling. The other two costs, maintenance of the landfill gas collection system and the energy generating facility are assumed to be costs that would have accrued regardless of the application of enhanced landfilling. It should be noted that the greater volumes of gas generated by enhanced landfilling may actually enable significant economics of scale for energy equipment and operations cost.

Table 8.
Capital Cost Estimate for a Hypothetical 1,000 kW Plant

COMPONENT	COST	PERCENTAGE
Collection System	$200,000	13.3
Fees - Planning/Environmental	$15,000	1.0
Legal Fees	$15,000	1.0
Interconnect Cost	$75,000	5.0
Generating Equipment	$970,000	64.7
Contingency	$225,000	15.0
TOTAL	$1,500,000	100.0

Source: Laidlaw Gas Recovery Systems, Jansen, G.R., (1992).

Table 9.
Estimated Operational Expenses for Enhanced Landfilling with a Landfill Gas-to-Energy Facility

COMPONENT	ANNUAL COST	SOURCE
Maintenance and Monitoring of Gas Field (40 acres) [2]	$10,000[1]	Yolo County estimate
Maintenance and Monitoring of Electrical Generating Facility (1,000 kW)	$150,000[1]	Laidlaw Gas Recovery Systems Jansen, G.R. (1992)
Increased Monitoring Costs	$5,000	Yolo County estimate
Maintenance and Management of Liquid Handling Equipment	$25,000	Yolo County estimate
TOTAL	$205,000	

1. These costs are assumed to be incurred whether or not enhancement is practiced as discussed in the text. Includes operation and maintenance of the landfill gas collection system.
2. Landfill gas from 40 acres of enhanced landfill is consistent with one MW of power generation.

<u>POTENTIAL INCREASE IN REVENUE FROM GAS-TO-ENERGY CONVERSION</u>
Methane recovery with enhanced landfilling may be conservatively assumed at 1 ft^3 per pound of dry waste (Augenstein, et. al. 1976a, 1976b, Barlaz, 1990). This is about threefold the "normally" observed recovery of around 0.6 ft^3 per dry pound because of higher generation rates and increased recovery efficiency. The surface membrane

containment technology proposed for capture of essentially all generated gas is commercially available and effective (Booth, 1991, Rice, 1994.) For a landfill receiving 500 tons per day, the methane recovery at ultimate steady state is thus 1.5 million ft^3 per day, enough to produce about 2 megawatts.

As previously discussed, gas generation from conventional landfilling is usually slow, sporadic and incomplete due to efforts to maintain the landfilled waste in as dry a state as possible. Also, well maintained clay surface liners can significantly reduce landfill gas production by effectively excluding moisture from the landfill while still allowing gas emissions to the atmosphere. Economic prospects for recovery of landfill gas and subsequent energy generation under these conditions are very poor. Landfills wishing to use landfill gas as an energy source can accrue substantial benefits from practicing enhanced landfilling, where the moisture regime in the landfill is controlled to accelerate decomposition, and the gas produced is effectively contained and collected.

ECONOMIC ANALYSIS OF ENHANCED LANDFILLING WITH ENERGY GENERATION

An economic analysis of enhanced landfilling at the Yolo County Central Landfill (YCCL) is presented in this section. A description of the analysis is provided below with assumptions and references for costs and benefit estimations.

The accounting stance taken in this economic analysis is that of an owner/operator of both the landfill and the power generation from landfill gas facility. At the Yolo County Central Landfill this is not the existing situation. Yolo County contracts with a private enterprise in the energy industry to operate the electricity generation facility. A result of this accounting stance is that royalties paid by the producer of electrical power (the private enterprise) to the owner of the landfill (Yolo County) are not considered.

It is assumed that in the year 1997 a module at the YCCL is constructed and begins accepting waste. It is further assumed that waste placed in this module and subsequently modules will experience liquid additions similar to those in the enhanced cell of the demonstration project. The tonnages of waste placed in the landfill each year in this analysis are based on waste disposal projections for the YCCL. These are shown in Table 1 in Appendix 3. The waste disposal projections determine the landfill module construction schedule and the amount of landfill gas generation that can be estimated each year. Based on these projections and currently estimated landfill capacity, the landfill capacity is calculated to be exhausted in the year 2020. Leachate recirculation is assumed to continue for an additional ten years when landfill gas generation is assumed to cease. This is discussed further in the following section.

The average depth of waste at the Yolo County Central Landfill is 40 feet. The economics of enhanced landfilling will be different for landfills with waste depths different than at Yolo County.

The inflation adjusted discount rate used in this analysis is 3% (Anex, 1996).

A spreadsheet is used for all calculations associated with this analysis. The spreadsheets generated in conducting this analysis are shown in Appendix 3.

<u>Landfill Methane Generation</u>

The amount of landfill methane generation is estimated at 1.8 ft^3 per dry pound of municipal solid waste (Augenstein etal., 1976a, 1976b, Barlaz, 1990). The moisture content of as-placed municipal solid waste is estimated at 25% on a weight basis. Therefore, the equation used to estimate methane potential for a given tonnage of waste is as follows.

Methane potential = (Tons landfilled)*(2000 lbs./ton)*(75 lbs. dry waste/100 lbs. as-placed waste)*(1.8 ft^3 CH_4/dry lb. waste)

It is assumed that with enhanced landfilling, the rate of generation of landfill gas will be accelerated such that landfill gas generation would cease after 10 years. Therefore, the ultimate methane yield would be realized in 10 years and the landfilled waste would possess no potential for further methane generation. For simplification, the yearly methane generation is assumed to be steady state and equal to the methane potential of the waste divided by 10 years.

It is assumed that waste placed in Year(i) would not begin generating methane until Year (i +1). Furthermore, it is assumed that during the first year of landfill gas generation there is no landfill gas recovery. This is because it takes time to construct the landfill gas recovery system and landfill gas recovery would not occur during this time. Therefore, 10% of the total methane potential of the waste is assumed to be lost due to the fact that the collection system is not yet in place. Therefore, in this analysis, methane recovery from waste placed in Year(i) would not occur until Year(i + 2). Of course, landfill gas will begin to be generated soon after waste placement, however, not at the accelerated rate that will occur with enhanced landfilling. Since liquid addition is not expected to begin until after the landfill gas recovery system is in place, the estimate of 10% of landfill gas being lost is a conservative estimate that does not serve to improve the economics of enhanced landfilling.

It is also assumed that a permeable layer is placed over the waste, such as a shredded tire layer, and that a synthetic liner is placed over the permeable layer, enabling a high recovery efficiency of 95% of methane gas generated. Methane flowrates from the Yolo County Central Landfill (YCCL), assuming that enhancement is applied, are shown in Table 1 in Appendix 3.

The method of using a spreadsheet to add the individual contributions from the tonnage of waste landfilled in each year is shown in Table 2. Each year's tonnage is assumed to generate an equal amount of landfill gas over ten years, although only 9 years worth of this gas is assumed to be recovered.

Energy Content of Landfill Methane

The heat energy potential of the methane gas is estimated assuming 900 BTU per ft^3 of methane (Augenstein and Pacey, 1992). Electrical energy potential is estimated using a heat rate of 12,500 BTU per kWhr (Augenstein and Pacey, 1992). Therefore, one million cubic feet of landfill methane has a BTU content of (900 BTU/ft^3 CH_4)(1,000,000 ft^3 CH_4) = 900,000,000 BTU. The electrical energy potential for one million cubic feet of landfill methane is estimated as (900,000,000 BTU/12,500 BTU per kWh) = 72,000 kWh. Energy potential of landfill methane generated at the YCCL is shown in Table 3 in Appendix 3.

Incremental Increase in Cost of Enhanced Landfilling above Conventional Landfilling

This analysis considers costs that would be incurred in the practice of enhanced landfilling that would not be incurred if conventional landfilling is practiced. Some cost components are considered mandatory for conventional landfill operations and, therefore, are not considered as costs accruing to enhanced landfilling. For example, the cost of the surface liner system that is placed at landfill closure is considered to be a cost for both conventional and enhanced landfills and is therefore not considered to be a cost accruing to enhanced landfilling. The same is true for the construction, operation, and maintenance of the landfill gas recovery system. Any landfill large enough that energy generation would be considered would be required to install a gas recovery system simply to comply with the US Clean Air Act.

Costs Associated with Enhanced Landfilling

In this analysis, all of the costs associated with energy generation are considered as accruing to enhanced landfilling even though energy generation could also be practiced with conventional landfilling. In the case of energy recovery with conventional landfilling, equipment costs will be spread out over more years because the methane gas is generated slower than with enhanced landfilling. Also, with conventional landfilling, the amount of energy generating equipment required to maximize energy generation from landfill methane is less than with enhanced landfilling. This is because the energy generation rate and methane yield is less with conventional landfilling; with enhanced landfilling more energy generating equipment is required over a shorter period of time to take advantage of the increased methane available. Therefore, with regards to the cost of acquiring energy generation equipment, this analysis is conservative with respect to enhanced landfilling. Rather than considering the incremental increase in cost to acquire the additional energy generating equipment to burn the incremental increase in methane available from enhancement, all of the energy generating equipment is accrued to enhanced landfilling.

Energy Generating Equipment

The cost to acquire energy generating equipment is $970,000 (1992 dollars) per megawatt (MW) of power generation capacity. The cost of operations and maintenance is estimated at $100,000 (1992 dollars) per MW of power generated. The source of this information is Laidlaw Gas Recovery Systems (Augenstein and Pacey, 1992). The permitting fees, legal fees, interconnect costs, and contingency total $300,000 in year 1992 dollars.

Decommissioning of the energy generating facility is estimated at $250,000 in the year 2030.

Additional Liner Costs

Additional waste management units are constructed at the Yolo County Central Landfill about every two years. The projected surface area of a module is about 22 acres. Depending on the regulatory perspective in a given area and specific site conditions, a conventional composite landfill liner system (single synthetic liner) may be allowed when enhanced landfilling is practiced. However, a double liner system may be required by regulators if liquid is to be added to the landfill. The additional cost to construct a secondary liner system is estimated at $50,000 per acre (Yolo County cost estimate, 1997 dollars).

Liquid System Management System Construction and O&M Costs

The system required to add liquid or recycle leachate into the landfill is considered a cost accruing to enhanced landfilling. However, some of the equipment that would be used to manage leachate for enhanced landfilling would also be required if conventional landfilling were practiced. The estimated cost to construct a landfill liquid addition/leachate recirculation system is $200,000 in 1997 dollars for a landfill module with a base surface area of 22 acres. This includes pumps, pipelines, and infiltration systems. Operations and maintenance of the liquid management system is estimated at $25,000, beginning in the year 2000. This includes monitoring the system, maintaining the infrastructure, and additional electricity costs above those accrued from conventional landfilling.

<u>Benefits of Enhanced Landfilling</u>

The most obvious benefit of enhanced landfilling is [illegible]ry generation from landfill methane. Other benefits are derived from leachate m[illegible]ement and early stabilization of the landfilled waste. These benefits are discussed be[illegible]

Landfill Methane to Energy Revenue

This analysis assumes that landfill methane is converted to electrical energy. The selling price per kWh is varied; a sensitivity analysis is conducted to determine the selling price per kWh required to achieve a benefit to cost ratio of one for four scenarios. These scenarios are described later in this report. The benefit to cost ratio is defined as the present value of benefits divided by the present value of costs. In the computation of energy revenue from landfill gas a down-time for energy generating equipment of 20% is assumed.

Tax Credits

Tax credits are available to producers of energy from landfill gas until the 2007. The tax credit available in 1997 is $1.00 per BTU of landfill methane generated. Following the year 1997, the tax credit is increased in each subsequent until the year 2007 (NEO Corporation). Of course, a public agency that does not pay taxes will not benefit from tax credits. However, a partnership with a private enterprise can be formed that would allow at least some portion of the tax credit benefit to be realized. The tax credits are shown in the benefit spreadsheets in Appendix 3.

Leachate Treatment Cost Savings

The recirculation of landfill leachate has been shown to result in a leachate with a reduced pollution load. This treatment benefit from recirculation can result in lower costs paid to a wastewater treatment facility or can preclude the necessity of a leachate pretreatment system prior to discharge to a wastewater treatment plant. Additionally, using the landfill for leachate storage can equalize leachate flows such that leachate is disposed of with a relatively constant flowrate. This can reduce treatment costs and reduce the need to construct leachate storage facilities. The estimated benefit is $25,000 in 1999, the first year that a leachate treatment benefit is expected to accrue. The $25,000 leachate treatment cost is assumed to increase to $250,000 in 2029. The projected cost of leachate treatment is uncertain and is based on the avoided cost of leachate pre-treatment prior to discharge, and the avoided cost of additional leachate surface impoundments.

Landfill Life Extension Benefits

The accelerated stabilization of the landfill will result in accelerated settlement of the landfill and, possibly, landfill life extension. Typically, in conventional landfills, this settlement occurs over a period of time too long to take advantage of the increased landfill airspace. To achieve this benefit it would be necessary to return to already stabilized landfill modules and add additional waste to increase the landfill height to its pre-settlement elevation. This approach might not be cost effective if a final cover system had already been placed on the landfill module. However, if this accelerated settlement were reliable, it might be possible to gain regulatory approval to landfill waste to an elevation higher than the ultimate regulated elevation knowing that with enhanced landfilling the final elevation would be within the maximum allowed height. For example, if the maximum regulated height were 80 feet, it might be possible to landfill to an elevation of 84 feet knowing that within 10 years the final elevation would settle to 80 feet or less.

This analysis assumes a landfill life extension of 5 years due to accelerated settlement for a landfill life of 23 years. The value placed on this airspace gained is the calculated as follows. The cost to permit and construct another landfill is estimated at between 11 and 12 million dollars in 1997 dollars. Using a discount rate of 3%, and a cost to open a new landfill in 1997 of $11,590,000, the discounted cost in the year 2020 is $22,873,867. However, it is assumed that enhanced landfilling has resulted in an extension of landfill life for an additional five years. Therefore, the expense of opening a new landfill can be postponed for five years. The increase in value of the $22,873,867 over that five year period, still using a 3% discount rate, is 3.64 million dollars. This benefit is assigned in the year 2025.

Post-Closure Monitoring and Maintenance Savings

If the landfill is stabilized in ten years following closure, the monitoring and maintenance of the gas recovery system can be discontinued. The cost to perform these tasks have been estimated at $20,000 per year in 1997 dollars.

Salvage Value of Electrical Power Generating Equipment
The salvage value of the electrical power generating equipment is assumed to be $60,000 per MW. This cost was not discounted. The salvage value is assumed to be the same at all points in time.

RESULTS

A sensitivity analysis was done to assess how uncertainty in certain assumptions would affect the results of the analysis. The analysis is performed with and without the cost of a double composite liner, and with and without the benefit of landfill life extension. This results in four scenarios being analyzed. The approach of the sensitivity analysis is to adjust the selling price of energy, the amount paid per kilowatt-hour, until the benefit to cost ratio is equal to one. Four cases were analyzed and are described below.

CASE 1: Case 1 assumes that liquid addition and leachate recirculation will be allowed without a double liner. Additionally, Case 1 assumes that the five year landfill life extension would be realized. For Case 1 only, the discount rate is also varied from 2 to 4% to evaluate the change in electricity selling price if the benefit to cost ratio is held equal to one.

CASE 2: Case 2 also assumes that the construction of a double liner will not be necessary. However, Case 2 differs from Case 1 in that no landfill life extension is realized. The benefit from the five year landfill life extension is eliminated.

CASE 3: Case 3 assumes that a double liner will be necessary at a cost of $50,000 per acre for additional construction costs. Case 3 also assumes that there will be a five year landfill life extension.

CASE 4: Case 4 assumes that a double liner at $50,000 per acre will be required and that there will not be any landfill life extension.

Table 10
Enhanced Landfilling Economic Sensitivity Analysis

SCENARIO	DESCRIPTION	cents/kWh for B/C = 1
Case 1	Single composite liner with landfill life extension of five years.	3.49
Case 2	Single composite liner with no landfill life extension.	3.93
Case 3	Double liner system with a five year landfill life extension.	7.77
Case 4	Double liner system without any landfill life extension.	8.22

B/C = benefit to cost ratio

TABLE 11
EFFECT OF ELIMINATING TAX CREDITS
B/C HELD CONSTANT AT 1

SCENARIO	ENERGY SELLING PRICE WITHOUT TAX CREDITS (cents per kWh)	INCREASE IN ENERGY SELLING PRICE FROM SCENARIOS WITH TAX CREDITS (cents per kWh)
Case 1	4.05	0.56
Case 2	4.45	0.52
Case 3	8.30	0.53
Case 4	8.75	0.53

Results of the sensitivity analysis are presented in Table 10 of this section. The effect of eliminating tax credits as a benefit are shown in Tale 11 of this section. Spreadsheets showing the costs and benefits throughout landfill life are shown in Tables 4 - 11 of Appendix 3. The present values of costs and benefits over the analysis period (1997 - 2050) are shown for all cases in Figures 1 - 4 of Appendix 3. It can be seen in Figures 1 - 4 that even though the benefit to cost ratio may be equal to one, there remain a number of years when cash flows are negative. This is due to the fact that energy generation equipment is expensive and these purchases occur relatively early in the project compared to some of the benefits. The information presented in Table 10 is also presented graphically in Figures 5 - 8 (Appendix 3), which show the change in benefit to cost ratios for a range of energy selling prices. The changes in energy selling price ($ per kWh) for a range of discount rates are shown graphically in Figure 9 of Appendix 3.

CONCLUSION

There is considerable uncertainty involved in this analysis. Economic projections 30-50 years into the future can only be considered to be very approximate. Regulatory requirements are difficult to predict, the energy industry is undergoing restructuring, the discount rate of 3% could change in the future. The analysis used Yolo County Central Landfill as a model; other sites could have conditions that are completely different than Yolo County and render the application of these results difficult. However, given the assumptions used in this analysis, enhanced landfilling can be accomplished with a benefit to cost ratio equal to one at a selling price for electricity of 3.5 - 4 cents per kWh for Cases 1 & 2 when a double composite liner system is not required. Requiring the use of a double liner system would render enhanced landfilling uneconomical. Electrical generation equipment is expensive to purchase and operate and increases in costs of this component would adversely affect the economics of enhanced landfilling. Also, because cash flows are often negative in spite of the benefit to cost ratios being equal to one, cash flow difficulties can be a problem during the period of landfill gas generation and energy recovery.